AIR QUALITY
ATIKOKAN

Annual Report
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Ministry
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AIR QUALITY

ATIKOKAN

ANNUAL REPORT, 1975

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NORTHWESTERN REGION
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CONTENTS

SUMMARY

Air quality investigations in the Atikokan area began in 1964, prior to the start-up of iron ore pelletizing plants operated by Steep Rock Iron Mines Limited and Caland Ore Company Limited. Air assessment programs carried out by the mining companies, Ministry of the Environment and Ontario Hydro have included vegetation, soil and snow sampling, and ambient air monitoring.

Vegetation in the vicinity of both pelletizing plants was found to contain moderately elevated levels of arsenic and very high concentrations of iron. Highest levels of both pollutants occurred northeast of Caland Ore's plant area, and declined with increasing distance from both mining operations. Visible adverse effects to local vegetation were not observed.

Snow samples near the mines were also contaminated with arsenic and iron and the pattern of distribution of these elements in snow was about the same as that determined for vegetation.

Dustfall and suspended particulate levels were frequently above Ontario criteria near the two mining operations. Iron content in suspended particulate was often high, but arsenic was well below the proposed provincial criterion. Concentrations of a range of heavy metals were also very low.

Sulphation rates were usually very low and the Ontario criterion was not exceeded. Sulphur dioxide levels, during the 1975 growing season, were also below criteria, as were concentrations of nitrogen dioxide. Above criteria values of ozone, however, were frequently recorded, but local industry was not implicated as the cause.

Evidence from all environmental studies indicates that arsenic and iron contamination in the vicinity of the two iron mines has been caused by airborne dust emissions from pelletizing plants, from ore zone blasting operations, and from ore transport and storage.

INTRODUCTION

Air quality investigations began in the Atikokan area in 1964 in connection with the establishment of two iron ore pelletizing plants located about 8 kilometres north of the town of Atikokan. Vegetation samples were first collected by Caland Ore Company Limited in the autumn of 1964 at 40 sites along eight radii centred on the location of their proposed mill. Steep Rock Iron Mines Limited, 3.2 km west of Caland, joined this survey program in 1966 and the number of sample points was increased to 55, Steep Rock servicing 28 of the sites and Caland 27. These company surveys, with modifications, continued until 1974. The pelletizing plants began operating in 1966 (Caland) and 1967 (Steep Rock). Ministry of the Environment began vegetation and soil sampling surveys at Atikokan in 1971 and continued these to 1975. The Ministry supplemented this work with a snow sampling program in 1974 and 1975.

An ambient air monitoring network was operated by both companies from 1966 to 1974. This included measurement of total dustfall, arsenic in dustfall, total suspended particulate, arsenic and heavy metal concentrations in suspended particulate, and sulphation rates. By 1975, having accumulated several years of data, the air monitoring survey was considerably revised and a number of stations were terminated. Continuous analysers for sulphur dioxide, nitrogen dioxide and ozone, were operated by a consulting firm for six months in 1975.

VEGETATION AND SOIL ASSESSMENT

(a) Methods

From 1964 to 1971, Caland and Steep Rock collected foliage samples in early and late summer from mixed broad-leaved and mixed coniferous species. In 1972, mixed collections were replaced by one broad-leaved species (trembling aspen) and one conifer (balsam fir). In the same year, sampling frequency was reduced from twice to once each growing season. All material collected was analysed for arsenic content only.

The first Ministry of the Environment survey, in 1971, included vegetation and soil from 17 sites, most of which were near locations sampled by the two companies. With modifications, this program continued until 1975. Analyses were carried out for aluminum, arsenic, cadmium, iron, sulphur and zinc in 1971 and 1972. In 1973, this list was reduced to aluminum, arsenic, iron and sulphur. Only arsenic and iron determinations were made in 1974 and 1975. To determine the effects of heavy deposits of iron oxide dust on leaf cell structure, jackpine and trembling aspen foliage was collected in 1974 from a site near one of the pelletizing plants.

(b) Results

Vegetation foliage sampled in 1964 and 1965, before the pelletizing plants became operational, contained less than one part per million (ppm) arsenic. Data from the two companies for the period 1966-71, showed that moderately elevated arsenic concentrations occurred in vegetation near both plants and that arsenic levels decreased with increasing distance from both mills. Ministry of the Environment data from 1971 to 1973 generally agreed with results obtained by Caland and Steep Rock. Ministry surveys in 1974 confirmed earlier findings: the occurrence of a zone of arsenic contamination near both plants, with highest arsenic concentrations to the northeast of Caland. The maximum arsenic content recorded in trembling aspen foliage in 1974 was 23 ppm, at a distance of 1 km northeast of Caland. The distribution pattern of arsenic in soil was about the same as that for vegetation. Also, surface soil (0-5 cm) consistently contained more arsenic than subsurface soil (5-10 cm), indicating that arsenic contamination was airborne. Arsenic levels were low in the town of Atikokan.*

Sampling locations used for the 1975 growing season are shown in Figure 1. Arsenic results, with comparative values for earlier

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*Griffin, H.D., 1975. Air quality investigations, Atikokan, 1964-74. Internal report.

years, are tabulated in Table 1. Using a SYMAP computer program developed by Harvard University, the arsenic data were also arranged into a contour map (Figure 2). This map clearly indicates the presence of elevated arsenic concentrations to the northeast of Caland. However, 1975 levels were generally lower than those in 1974 (Table 1), possibly reflecting benefits to the environment from a labour strike which closed both pelletizing plants from mid-May to late July. During the course of Ministry of the Environment investigations, no visible adverse effects attributable to arsenic contamination were observed on vegetation in the vicinity of the Atikokan iron mining operations. Despite this, arsenic concentrations above 10 ppm are cause for concern since sensitive plant species (not known to occur in the Atikokan area) may be adversely affected by arsenic levels of this magnitude.

Excessive iron concentrations have been regularly recorded in vegetation near Caland and Steep Rock operations, and deposits of reddish iron oxide dust have been readily apparent on all vegetation in the vicinity. The maximum extent of visible dust contamination has been about 2.5 km northeast of Caland, and the highest levels of iron in trembling aspen foliage have usually been found in the same direction. Iron in vegetation has displayed a distinct concentration gradient with distance from the pelletizing plants but iron in soil has not, further evidence that iron contamination was airborne. Foliar injury attributable to iron dust deposits has not been observed. Histological examination of jackpine foliage 400 metres from one of the pelletizing plants revealed that iron dust particles accumulated on leaf surfaces and in stomatal openings. On trembling aspen leaves, particles were embedded in the leaf cuticle and were concentrated on lower surfaces of leaves. No dust particles were found inside the leaves and no abnormalities were observed in internal cell structure.

Surveillance results in 1975, with respect to iron investigation, were similar to those for earlier years (Table 1). The modest decline in iron levels in 1975 might be attributed to shut-down conditions at the two pelletizing plants in the spring and early summer. A computer

map of iron concentrations (Figure 3) clearly demonstrates the general pattern of contamination which has existed since pelletizing operations began.

SNOW SAMPLING

Snow samples in the vicinity of Atikokan iron mining operations were obtained from 17 sites in 1974 and 25 sites in 1975. The meltwater obtained was analysed for aluminum, arsenic, iron and sulphate. Results of these surveys, reported earlier, demonstrated the presence of an area with slightly elevated aluminum and sulphate levels, significantly elevated arsenic, and excessive concentrations of iron. As noted for vegetation, highest arsenic and iron values in snow were recorded northeast of Caland Ore. Visible deposits of iron oxide dust were seen on and below the snow surface at most sample points, except in freshly fallen snow. These deposits were subjectively ranked as moderate to heavy within 1 km of both pelletizing plants, moderate up to 2 km northeast of Caland, trace to light at other sample sites except at Nym Lake and control sites, where no dust was seen.

AIR MONITORING

(a) Dustfall

Dustfall is one of the most visible classes of air pollutants. It comprises particulate matter which settles out from the atmosphere under the influence of gravity. It is measured by exposing open-top vessels for 30 days and weighing the collected matter. Results are expressed in tons per square mile per month.

Figure 4 shows dustfall monitoring sites used at various intervals from 1967 to 1975. An historical summary of the data from 1967 to 1974 is given in Table 2, and Table 4 shows monthly values for 1975. Annual averages are plotted in Figure 5. As expected, some very high dustfall measurements, often well above the Ontario criteria, were made near the two pelletizing plants. The distribution of dustfall

levels was not unlike the distribution of arsenic and iron in vegetation and snow. Arsenic in dustfall, summarized in Table 3 and plotted in Figure 6, showed the same distribution pattern. Although no criteria have been established for arsenic in dustfall, a guideline of 4 pounds per acre per annum has been used. Only twice in an 8-year period were levels found above this guideline.

(b) Suspended Particulate

Suspended particulate constitutes particulate matter of small size which remains in the atmosphere for extended periods. A known volume of air is drawn through pre-weighed glass fibre filters for 24-hour periods and the filters are then re-weighed to determine the quantity of dust collected. Results are given in micrograms per cubic metre of air ($\mu g/m^3$). Exposed filters from the Atikokan survey were usually analysed for arsenic content and, in 1971-72, for a variety of heavy metals.

Monitoring locations are shown on Figure 7. Suspended particulate levels, with values for arsenic and iron content, are presented in Table 5 for all stations during the 1966-1974 period. Average particulate loads, from 1966 to 1972, are plotted in Figure 8. Since sampling was restricted to about 12 filters a year per site (compared with a normal standard of 60), the data cannot be considered as representing all variations in local air quality. However, certain trends are evident: the Ontario criterion (120 $\mu g/m^3$ for 24 hours) was frequently exceeded, highest average levels occurred closest to the two sources, and iron content was often high. Arsenic concentrations were well below the proposed provincial criterion of 5 $\mu g/m^3$.

With the exception of lead at one location, concentrations of cadmium, chromium, copper, manganese, nickel, lead, vanadium and zinc in suspended particulate were very low throughout the survey area (Table 6). High levels of lead (maximum 36.6 $\mu g/m^3$) at station 62021 are not attributed to iron ore mining or processing operations, but the actual source was not identified.

Suspended particulate was monitored at only one site (station 62013) in 1975. Results are given in Table 7. The 24-hour criterion was exceeded only once and iron levels were low. The geometric mean for the year was 32 $\mu g/m^3$, well below the criterion of 60.

(c) Sulphation Rate

Sulphation rate is measured by exposing lead dioxide plates to the air for 30-day periods. Lead dioxide reacts with sulphur compounds in the atmosphere to form lead sulphate. Results are expressed in milligrams of sulphur trioxide per hundred square centimetres per day (mg $SO_3/100\ cm^2$/day). Because of its oxidizing power, lead dioxide converts other reactive sulphur compounds, such as hydrogen sulphide and mercaptans, into sulphate. At Atikokan, it is assumed that sulphur dioxide is the only potential reactive pollutant.

Sulphation monitoring sites are shown in Figure 7. Data from 1967 to 1974 are summarized in Table 8 and detailed monthly values for 1975 are given in Table 4. During the entire monitoring period the current criterion of 0.70 mg has never been exceeded and the former criterion of 0.40 was exceeded only once (1970). Most values are barely above the detection limit, and indicate the general absence of sulphur-containing air pollutants in the area.

(d) Continuous Monitoring

As part of an environmental study for Ontario Hydro, Acres Consulting Services Limited operated a small network of continuous ambient air monitors from June to November, 1975. Their locations are shown in Figure 10. Sulphur dioxide was monitored at all five stations and, in addition, ozone and nitrogen oxides were recorded at Sites A and E. Detailed results for the whole monitoring periods are not yet available, but a summary has been prepared in Table 9.

(i) Sulphur Dioxide

No provincial criteria were exceeded during the 6-month monitoring period. The highest hourly average, 0.24 ppm, occurred on September 20 at station C.

(ii) Nitrogen Oxides

Nitrogen oxides were also well below Ontario criteria. Highest values were recorded at station E (Nym Lake).

(iii) Ozone

Ozone levels were higher than expected and the hourly criterion (0.08 ppm) was often exceeded, particularly in July. The reason(s) for elevated ozone concentrations in the Atikokan area has not been established, but natural phenomena may be involved. Local industrial sources are not implicated.

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- Air Quality Laboratory, Laboratory Branch, for chemical analysis of vegetation, for preparing and analysing sulphation plates, and for iron determinations in suspended particulate.
- Phytotoxicology Section, Air Resources Branch, for technical advice, for preparing computer SYMAPS, and for processing vegetation samples.
- Regional Laboratory, Northwestern Region, for chemical analysis of snow meltwater, and for dustfall and suspended particulate weight determinations.
- Steep Rock Iron Mines Limited and Caland Ore Company Limited, for operation of the dustfall and sulphation monitoring network, for dustfall weight determinations, and for assistance with vegetation and snow sampling.
- Atmospheric Environment Service, Atikokan, for operation of a high volume air sampling unit.

- Inorganic Trace Contaminants Section, Laboratory Branch, for chemical analysis of snow meltwater.

TABLE 1. Arsenic and iron content (ppm, dry weight) in trembling aspen foliage, Atikokan, 1971-1975.

Location	Arsenic* 1971-73	Arsenic* 1974	Arsenic* 1975	Iron** 1971-73	Iron** 1974	Iron** 1975
SR-N-2		4.0	2.5		355	205
SR-NE-0.5			5.1			520
SR-NE-2	7.1	8.7	9.7	955	910	965
SR-E-1	6.2	19.0	5.8	1255	1440	905
SR-S-1			2.7			1255
SR-S-2		3.8	1.1		830	360
SR-SW-2	4.5	3.2	1.2	540	945	340
SR-W-0.5	8.9	5.5	1.4	2790	950	510
SR-W-2		2.8	0.7		390	100
SR-NW-1		3.1	2.2		720	550
SR-NW-2		2.0	1.2		325	120
CO-N-1		5.7	4.5		900	475
CO-NNE-1.5			7.6			920
CO-N-3		3.8	2.6		410	295
CO-NE-0.5			52.1			10600
CO-NE-1		22.7	17.5		6000	3660
CO-NE-2	5.6	9.5	7.5	1470	1640	1125
CO-NE-2.7			6.0			970
CO-NE-3	4.2	4.0	3.1	260	420	210
CO-E-2		6.7	2.5		460	180
CO-SE-19			0.4			60
CO-S-0.5			3.8			935
CO-S-1		5.9	2.0		430	260
SR-S-6.4	1.5	1.1	0.3	120	172	90
Control east	0.5	0.4	<0.3	64	122	70
Control west	<0.5	<0.3	<0.3	65	80	65

*Not washed foliage. **Washed foliage.

TABLE 2. Annual average dustfall levels, Atikokan, 1967-1974.

Station	Distance(metres) and direction from SRIM*	Dustfall (tons/sq. mile/30 days)** 1967	1968	1969	1970	1971	1972	1973	1974
62004	4900 E						9 (16)	17 (21)	10 (15)
62005	3500 ESE						10 (27)	23 (93)	14 (75)
62007	3750 ENE						28 (68)	34 (65)	31 (52)
62008	2650 ENE						27 (87)	26 (46)	10 (20)
62009	3000 NE						14 (52)	15 (24)	9 (11)
62013	7900 SSE						8 (23)	9 (16)	7 (7)
62016	2500 S	19 (50)	43 (199)	23 (78)	20 (36)	12 (27)	13 (45)		
62017	600 SW	15 (30)	21 (51)	27 (59)	31 (64)	38 (125)	38 (118)		
62018	1750 W	9 (18)	10 (24)	14 (25)	14 (25)	12 (26)	15 (32)		
62019	800 NW	9 (26)	24 (57)	61 (128)	24 (48)	20 (46)	19 (28)		
62020	2400 N	7 (10)	15 (70)	14 (34)	16 (44)	12 (23)	10 (13)		
62021	750 SE	22 (53)	62 (144)	95 (163)	95 (212)	46 (76)	55 (113)		
62022	2400 N							11 (17)	9 (14)
62023	1750 W							19 (55)	14 (20)
62024	2250 SW							13 (33)	12 (18)
62025	3600 S							9 (30)	10 (18)
62026	800 NW							14 (21)	12 (23)
62027	550 ENE						63 (151)	40 (75)	24 (114)

*SRIM = Steep Rock Iron Mines Limited.

**Maximum monthly values given in parentheses.

TABLE 3. Annual average arsenic content in dustfall, Atikokan, 1967-1974.

Station	Distance(metres) and direction from SRIM*	Arsenic (lbs/acre/year)**							
		1967	1968	1969	1970	1971	1972	1973	1974
62004	4900 E						.30 (.57)	.30 (.49)	.16 (.52)
62005	3500 ESE						.30 (.95)	.30 (1.37)	.51 (2.81)
62007	3750 ENE						.90 (2.99)	1.00 (2.29)	.67 (1.73)
62008	2650 ENE						.70 (1.57)	.60 (1.44)	.27 (.79)
62009	3000 NE						.30 (.53)	.40 (1.36)	.20 (.37)
62013	7900 SSE						.10 (.15)	.05 (.10)	.30 (2.76)
62016	2500 S	.07 (.17)	.27 (1.52)	.15 (.23)	.22 (.53)	.20 (.42)	.17 (.30)		
62017	600 SW	.09 (.19)	.42 (.69)	.55 (1.08)	.41 (.68)	.78 (1.22)	.48 (.85)		
62018	1750 W	.08 (.27)	.29 (1.12)	.24 (.44)	.23 (.46)	.21 (.33)	.31 (.87)		
62019	800 NW	.16 (.48)	.40 (1.18)	.69 (1.22)	.61 (1.65)	.70 (1.86)	.51 (.88)		
62020	2400 N	.08 (.17)	.32 (.89)	.30 (.71)	.27 (.63)	.31 (.56)	.25 (.49)		
62021	750 SE	.26 (.81)	1.11 (4.51)	.90 (1.75)	1.55 (5.04)	.94 (1.69)	1.04 (2.24)		
62022	2400 N							.23 (.35)	.19 (.37)
62023	1750 W							.31 (.67)	.22 (.53)
62024	2250 SW							.18 (.50)	.10 (.16)
62025	3600 S							.16 (.32)	.14 (.20)
62026	800 NW							.29 (.37)	.18 (.33)
62027	550 ENE						1.00 (1.70)	.80 (1.96)	.39 (1.01)

*SRIM = Steep Rock Iron Mines Limited.
**Maximum monthly values given in parentheses.

TABLE 4. Dustfall and sulphation, Atikokan, 1975.

Station	Location	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
		Dustfall (tons/sq. mile/30 days)*												
62005	Fairweather	15	19			23	11	9	7	6	20	14	11	14
62013	Atikokan	6	15			17	8	50	16	14	15	10	6	16
62022	Mary Lake	8	4	3	6	6	5	9	10	6	12	8	3	7
62023	Water Tower	6	1	7	9	11	11	8	10	5	24	6	3	8
62025	Pal Lake Road	6	3	4	5	15	49	10	9	6	6	13	2	11
62060	Lime Point					36	17	13	7	9	21	21	13	17
62061	Moose Lake Dam					34	16	52	4	34	21		8	24
62062	Mando Road Dump					31	15	34	9	9	20	15	8	18

*Values exceeding criteria of 20 (monthly) or 13 (annual average) are underlined.

Station	Location	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
		Sulphation (mg SO_3/100 cm^2/day)**												
62005	Fairweather						.03	.03	.03	.03	.03	.03		.03
62013	Atikokan	.05	.03	.04			.03	.03	.03	.03	.03	.03	.03	.03
62022	Mary Lake	.05	.03	.03	.03	.03	.05	.03	.03	.03	.03	.03	.03	.03
62023	Water Tower	.03	.04	.03	.03	.03	.03	.04	.03	.03	.03	.03	.03	.03
62025	Pal Lake Road	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
62060	Lime Point						.03	.03	.03	.03	.03	.03	.03	.03
62061	Moose Lake Dam						.03	.03	.03	.03	.03	.03	.03	.03
62063	Nym Lake						.03	.03						.03

**Minimum value reported is 0.03 mg SO_3/100 cm^2/day.

TABLE 5. Arsenic and iron in suspended particulate, Atikokan, 1966-1974. (All values in µg/m^3)

Station	Year	Number of samples	TSP*		Arsenic		Iron	
			Mean	Max.	Mean	Max.	Mean	Max.
62005	1970	5	51	80				
	1971	18	53	171	< 0.1	0.4	10.3	55.3
	1972	10	45	66	0.1	0.5	8.6	8.6
62006	1970	6	153	353				
	1971	18	120	374	0.1	0.7	17.2	68.4
	1972	10	87	122	0.1	0.3	17.7	22.5
62008	1970	5	150	390				
	1971	18	93	184	< 0.1	0.3	19.2	38.1
	1972	10	52	106	0.1	0.3	12.9	22.4
62013	1966	5	40	93	< 0.1	0.4		
(town)	1967	20	38	79	< 0.1	0.2		
	1968	17	50	137	< 0.1	0.4		
	1969	12	51	89	0.1	0.4		
	1970	6	41	79	< 0.1	0.1		
	1971	16	52	111	< 0.1	0.1	3.5	8.3
	1972	10	48	126	< 0.1	< 0.1	0.1	1.4
62017	1966	7	137	304	< 0.1	0.2		
	1967	10	90	213	< 0.1	< 0.1		
	1968	12	238	710	< 0.1	0.6		
	1969	12	582	1820	0.2	1.0		
	1970	12	160	500	< 0.1	0.3		
	1971	12	90	330	< 0.1	0.4	31.0	132.4
	1972	6	58	80	0.1	0.3	3.4	3.4
62021	1966	7	111	238	< 0.1	0.1		
	1967	12	128	436	< 0.1	0.2		
	1968	12	172	505	< 0.1	0.2		
	1969	11	292	1510	0.1	0.4		
	1970	11	127	305	< 0.1	0.3		
	1971	12	123	340	< 0.1	0.3	17.0	70.7
	1972	6	180	185	< 0.1	< 0.1	7.3	7.3

*TSP = Total suspended particulate.

(continued)

TABLE 5. (continued)

Station	Year	Number of samples	TSP Mean	TSP Max.	Arsenic Mean	Arsenic Max.	Iron Mean	Iron Max.
62022	1966	7	69	109	< 0.1	< 0.1		
	1967	12	45	111	< 0.1	< 0.1		
	1968	12	65	220	< 0.1	0.2		
	1969	12	131	360	< 0.1	0.2		
	1970	11	27	143	0.2	0.9		
	1971	11	38	88	< 0.1	0.3	11.1	34.2
	1972	10	27	32	< 0.1	0.4	4.0	4.0
	1973	8			< 0.1	0.2		
	1974	12	26	128	< 0.1	0.2		
800 m W	1966	7	46	97	< 0.1	0.3		
	1967	12	70	141	< 0.1	0.3		
	1968	12	72	200	< 0.1	0.2		
	1969	12	177	585	< 0.1	0.3		
	1970	11	116	540	< 0.1	0.2		
	1971	12	58	161	< 0.1	0.3	14.5	59.6
	1972	7	285	757	< 0.1	< 0.1	18.2	18.2
62023	1973	11			< 0.1	0.5		
	1974	12	46	172	< 0.1	< 0.1		
62024	1973	11			< 0.1	0.5		
	1974	12	40	129	< 0.1	0.1		
62025	1973	11			< 0.1	0.3		
	1974	12	31	91	< 0.1	0.1		
62028	1970	6	275	397				
	1971	17	187	440	< 0.1	< 0.1	67.8	106.1
	1972	10	204	356	< 0.1	0.2	27.2	46.9

TABLE 6. Miscellaneous heavy metals in suspended particulate, Atikokan, 1971-1972.

Station	Year	Number of samples	TSP		Mean concentrations ($\mu g/m^3$)							
			Mean	Max.	Cd	Cr	Cu	Mn	Ni	Pb	Vn	Zn
62005	1971	18	53	171	<0.1	<0.1	0.3	<0.1	<0.1	0.5	<0.1	<0.1
	1972	4	45	66	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1
62006	1971	18	120	374	<0.1	<0.1	0.6	0.2	<0.1	0.1	<0.1	0.1
	1972	4	87	122	<0.1	<0.1	2.6	<0.1	<0.1	<0.1	<0.1	0.3
62008	1971	18	93	184	<0.1	<0.1	0.2	0.2	<0.1	0.1	<0.1	0.1
	1972	4	52	106	<0.1	<0.1	0.3	0.1	<0.1	<0.1	<0.1	0.2
62013	1971	16	52	111	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	<0.1	0.1
(town)	1972	4	48	126	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.4
62017	1971	12	90	330	<0.1	<0.1	0.2	0.3	<0.1	1.0	<0.1	1.6
	1972	1	58	80	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
62021	1971	12	123	340	<0.1	<0.1	0.2	0.2	<0.1	12.2	<0.1	1.8
	1972	1	180	185	<0.1	<0.1	<0.1	<0.1	<0.1	8.4	<0.1	<0.1
62022	1971	11	38	88	<0.1	<0.1	0.1	<0.1	<0.1	0.6	<0.1	1.3
	1972	1	27	32	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	4.0
800 m W	1971	12	58	161	<0.1	<0.1	<0.1	0.2	<0.1	0.3	0.2	1.5
	1972	1	285	757	<0.1	<0.1	<0.1	0.2	<0.1	0.2	0.2	
62028	1971	12	187	440	<0.1	0.1	<0.1	0.4	<0.1	0.2	<0.1	0.1
	1972	4	204	356	<0.1	0.1	<0.1	0.6	<0.1	<0.1	<0.1	0.4

TABLE 7. Total suspended particulate (TSP, $\mu g/m^3$) and iron ($\mu g/m^3$) in suspended particulate, Atikokan, 1975.

Date	TSP	Iron	Wind*	Date	TSP	Iron	Wind*
Jan. 6				July 5	38	1.7	SW 5
12				11	30	2.3	NW 8
18	18	0.7	NW 13	17	60	2.4	SW 14
24	13	0.7		23	26	1.3	SW 5
30	41	3.5	W 2	29	74	3.8	SW 10
Feb. 5	21	4.3	NW 6	Aug. 4	16	1.1	NW 10
11	11	0.6	E 5	10	29	1.5	NW 10
17	25	2.0	S 0	16	33	1.9	SW 11
23	22	5.6	NW 6	22	35	3.0	SE 8
				28	-	-	E 8
Mar. 1	43	3.7	W 8				
7	62	5.8	NW 8	Sept. 3	32	1.6	W 10
13	46	1.6	SW 6	9	32	2.1	S 6
19	40	2.8	S 18	15	46	2.9	SW 8
25	16	1.5	NE 11	21	29		NW 11
31	26	1.5	NW 6	27	125**		SW 3
Apr. 6	12	0.9	E 10	Oct. 3	92		NW 5
12	44	2.8	NE 2	9	31		SW 10
18	13	1.0	NW 6	15	12		NW 10
24	-		E 3	21	76		W 10
30	9	0.7	NE 8	27	46		W 6
May 6	37	1.9	E 10	Nov. 2	73		W 11
12	111	6.8	SW 8	8	78		W 6
18	61	2.8	SW 11	14	43		S 6
24	46	1.8	SW 11	20	6		NE 19
30	45	2.9	NW 6	26	-		C+ 1
June 5	20	1.0	NW 11	Dec. 2	48		C 3
11	35	1.5	N 3	8	40		C 0
17	53	1.8	S 5	14	22		NW 11
23	-	-	W 11	20	27		C 5
29	26	1.3	S 10	26	19		C 0

*Prevailing wind direction and speed in kilometres per hour.
**Values exceeding criterion of 120 $\mu g/m^3$ are underlined.
+C = Calm.

TABLE 8. Annual average sulphation rates, Atikokan, 1967-1974.

Station	Distance(metres) and direction from SRIM*	Sulphation ($\mu g/m^3$)**							
		1967	1968	1969	1970	1971	1972	1973	1974
62010	2100 ENE	.05 (.10)	.07 (.34)	.03 (.08)	.05 (.10)	.03 (.07)	.03 (.09)	.05 (.12)	.03 (.07)
62011	4900 E	.04 (.06)	.05 (.16)	.02 (.04)	.03 (.07)	.02 (.04)	.02 (.05)		
62012	4900 S	.04 (.07)	.03 (.08)	.02 (.06)	.06 (.28)	.03 (.07)	.03 (.08)		
62013	7900 ESE	.06 (.12)	.08 (.27)	.02 (.07)	.05 (.14)	.03 (.09)	.04 (.10)	.03 (.13)	.04 (.07)
62014	1600 N	.04 (.07)	.03 (.08)	.02 (.04)	.07 (.50)	.02 (.05)	.02 (.05)		
62015	1750 W	.04 (.07)	.06 (.22)	.02 (.04)	.04 (.11)	.03 (.06)	.02 (.04)		
62022	2400 N							.04 (.15)	.02 (.05)
62023	1750 W							.07 (.32)	.03 (.04)
62025	3600 S							.03 (.12)	.02 (.04)
62026	1150 NW							.05 (.12)	.03 (.08)

*SRIM = Steep Rock Iron Mines Limited.
**Maximum monthly values given in parentheses.

TABLE 9. Concentrations of sulphur dioxide, nitrogen oxides and ozone at Atikokan, June-November, 1975.

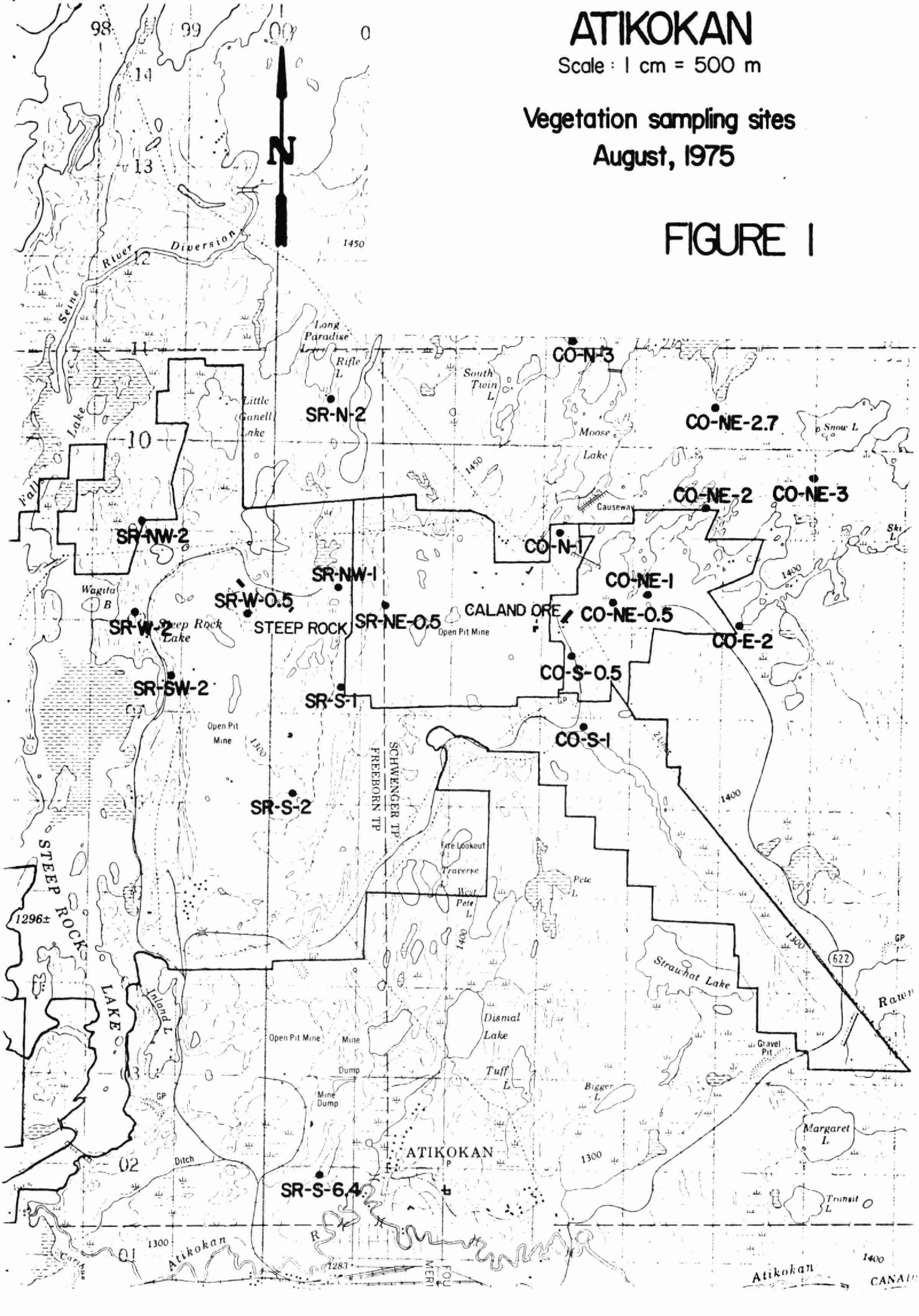
Averaging period	Concentration (ppm)					
	June	July	Aug.	Sept.	Oct.	Nov.
	Sulphur dioxide (all stations)					
Hourly maximum	.05	.08	.12	.24	.04	.09
Daily maximum	.04	.02	.05	.03	.02	.06
Monthly average	.01	.01	.01	.01	.01	.01
Occasions above hourly criterion	nil	nil	nil	nil	nil	nil
	Nitrogen oxides (stations A and E)					
Hourly maximum	.01	.03	.05	.10	.03	.04
Daily maximum	.01	.01	.02	.03	.02	.02
Monthly average	.01	.01	.01	.01	.01	.01
Occasions above hourly criterion	nil	nil	nil	nil	nil	nil
	Ozone (station A)					
Hourly maximum	.07	.10	.09	.10	.10	.07
Daily maximum	.07	.09	.07	.07	.06	.06
Monthly average	.04	.04	.04	.03	.03	.03
Occasions above hourly criterion	nil	72	21	33	15	nil
	Ozone (station E)					
Hourly maximum	.09	.10	.07	.09	.08	.05
Daily maximum	.07	.08	.07	.07	.06	.04
Monthly average	.05	.04	.03	.03	.03	.03
Occasions above hourly criterion	6	51	11	5	7	nil

ATIKOKAN

Scale : 1 cm = 500 m

Vegetation sampling sites
August, 1975

FIGURE I



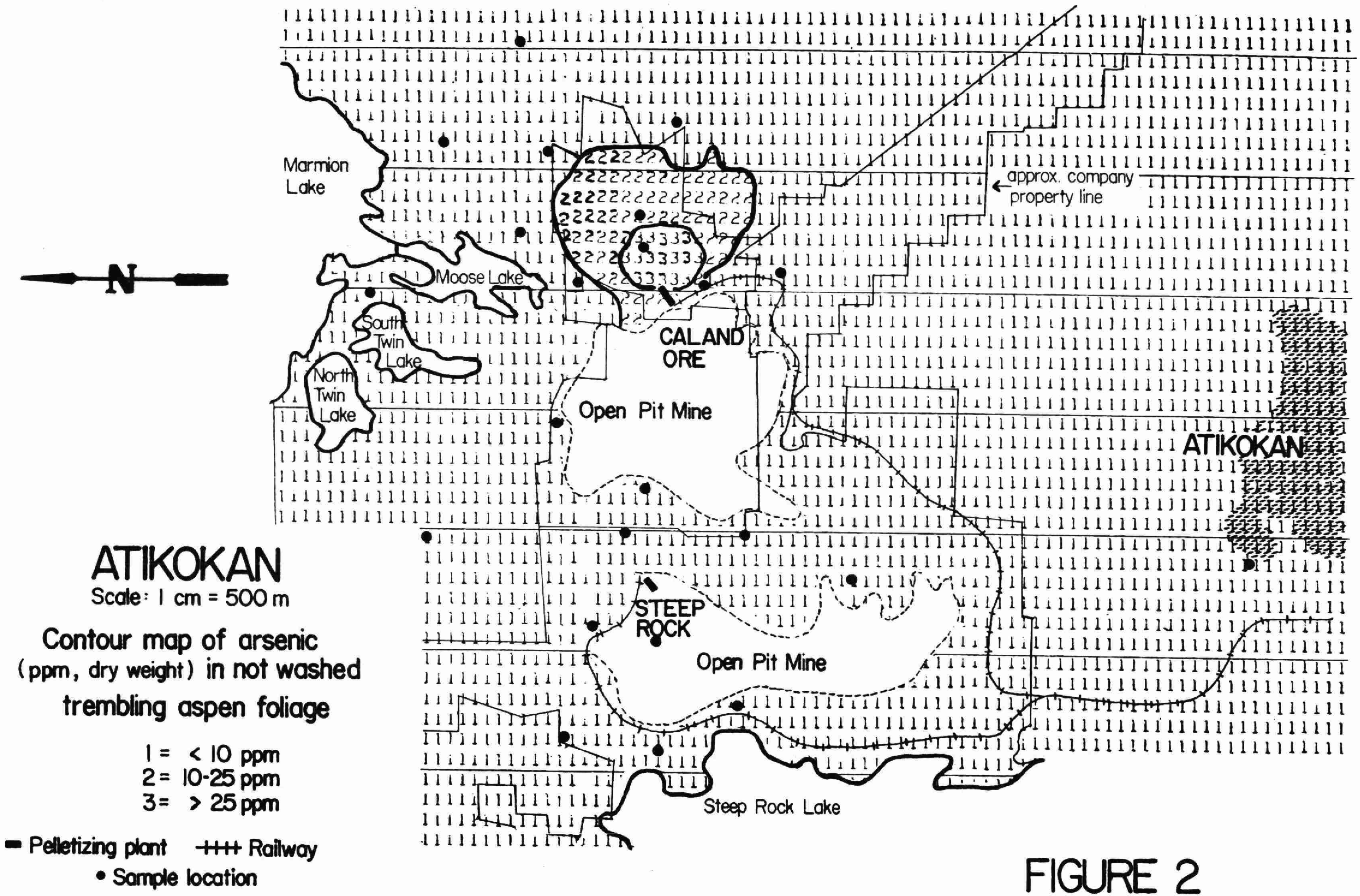
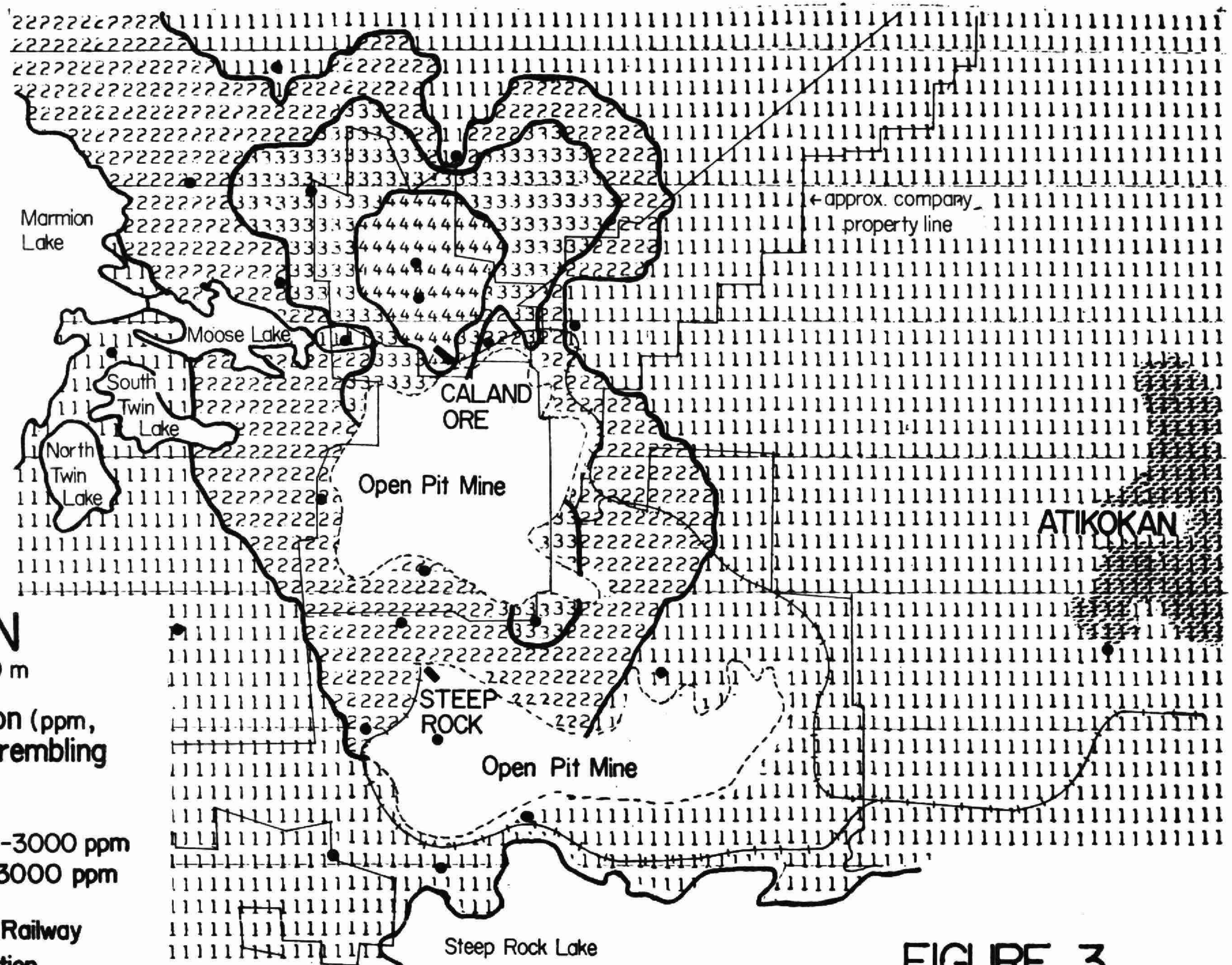

N
Marmion Lake
Moose Lake
South Twin Lake
North Twin Lake
CALAND ORE
Open Pit Mine
approx. company property line
ATIKOKAN
STEEP ROCK
Open Pit Mine
Steep Rock Lake
ATIKOKAN
Scale: 1 cm = 500 m
Contour map of arsenic (ppm, dry weight) in not washed trembling aspen foliage
1 = < 10 ppm
2 = 10-25 ppm
3 = > 25 ppm
Pelletizing plant
++++ Railway
• Sample location

FIGURE 2



ATIKOKAN

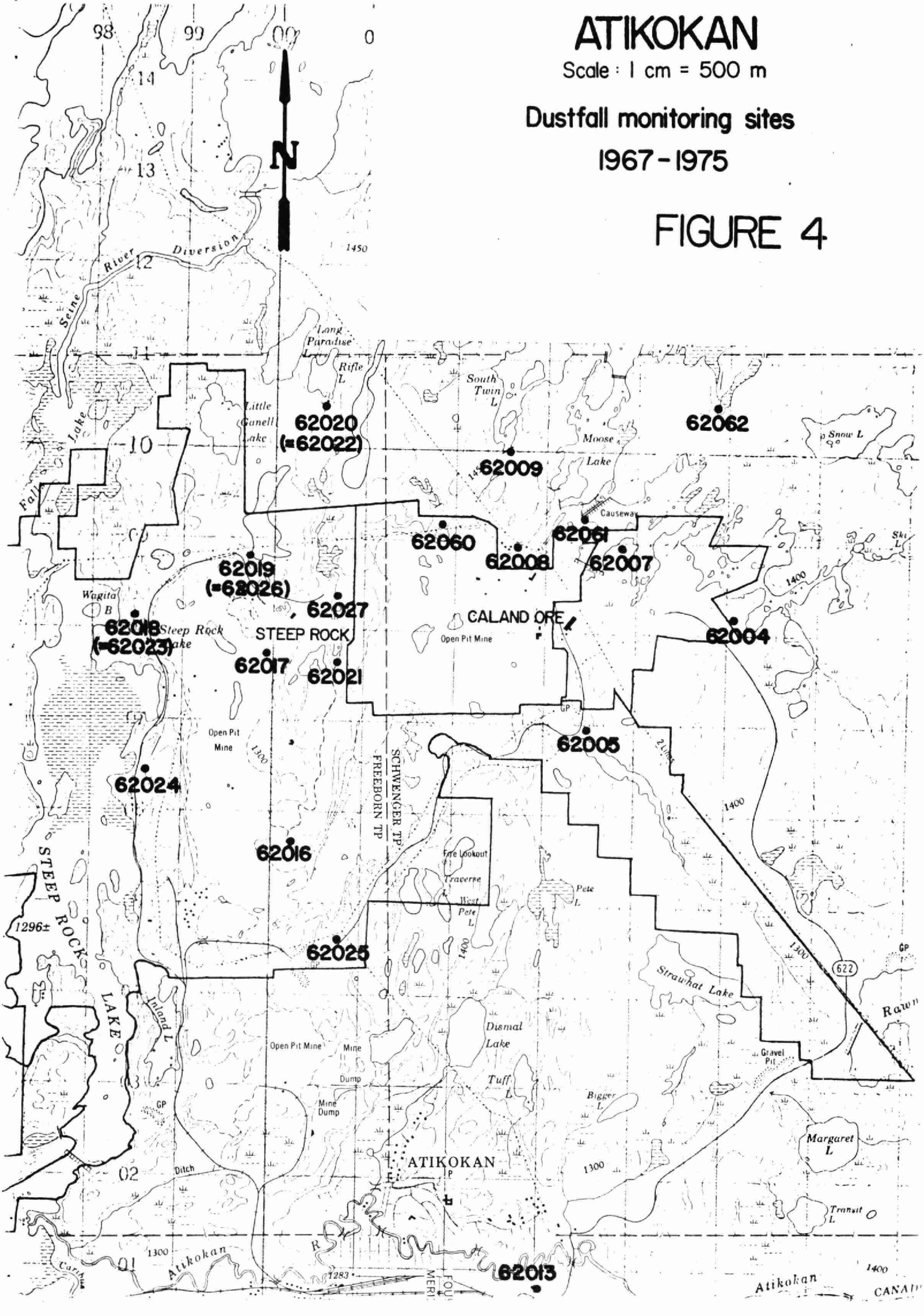
Scale: 1 cm = 500 m

Contour map of iron (ppm, dry weight) in washed trembling aspen foliage

1 = < 500 ppm 3 = 1000-3000 ppm
2 = 500-1000 ppm 4 = > 3000 ppm

▬ Pelletizing plant ++++ Railway
• Sample location

FIGURE 3



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Scale : 1 cm = 500 m

Dustfall monitoring sites

1967 - 1975

FIGURE 4

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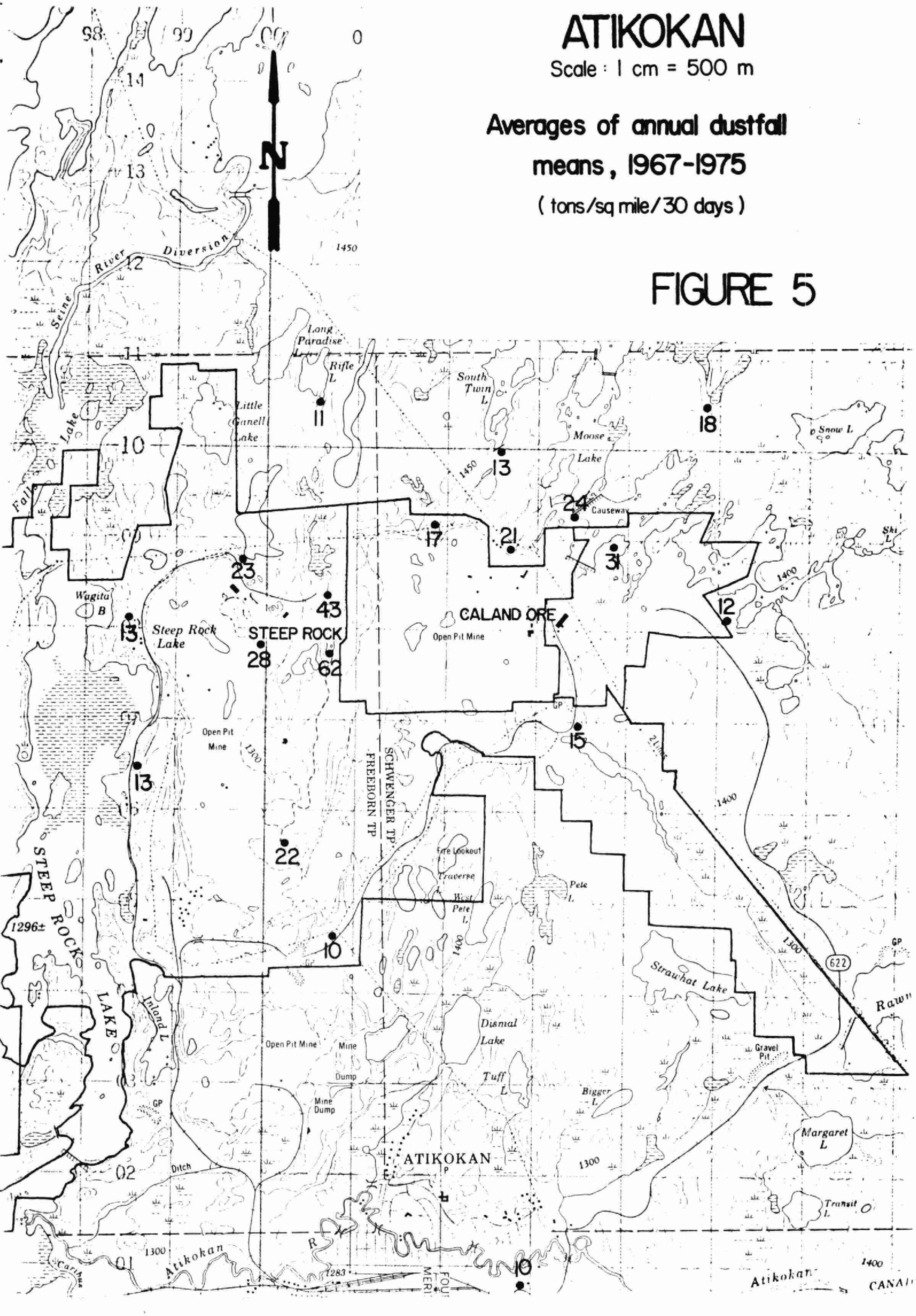
Scale : 1 cm = 500 m

Averages of annual dustfall means, 1967-1975

(tons/sq mile/30 days)

FIGURE 5



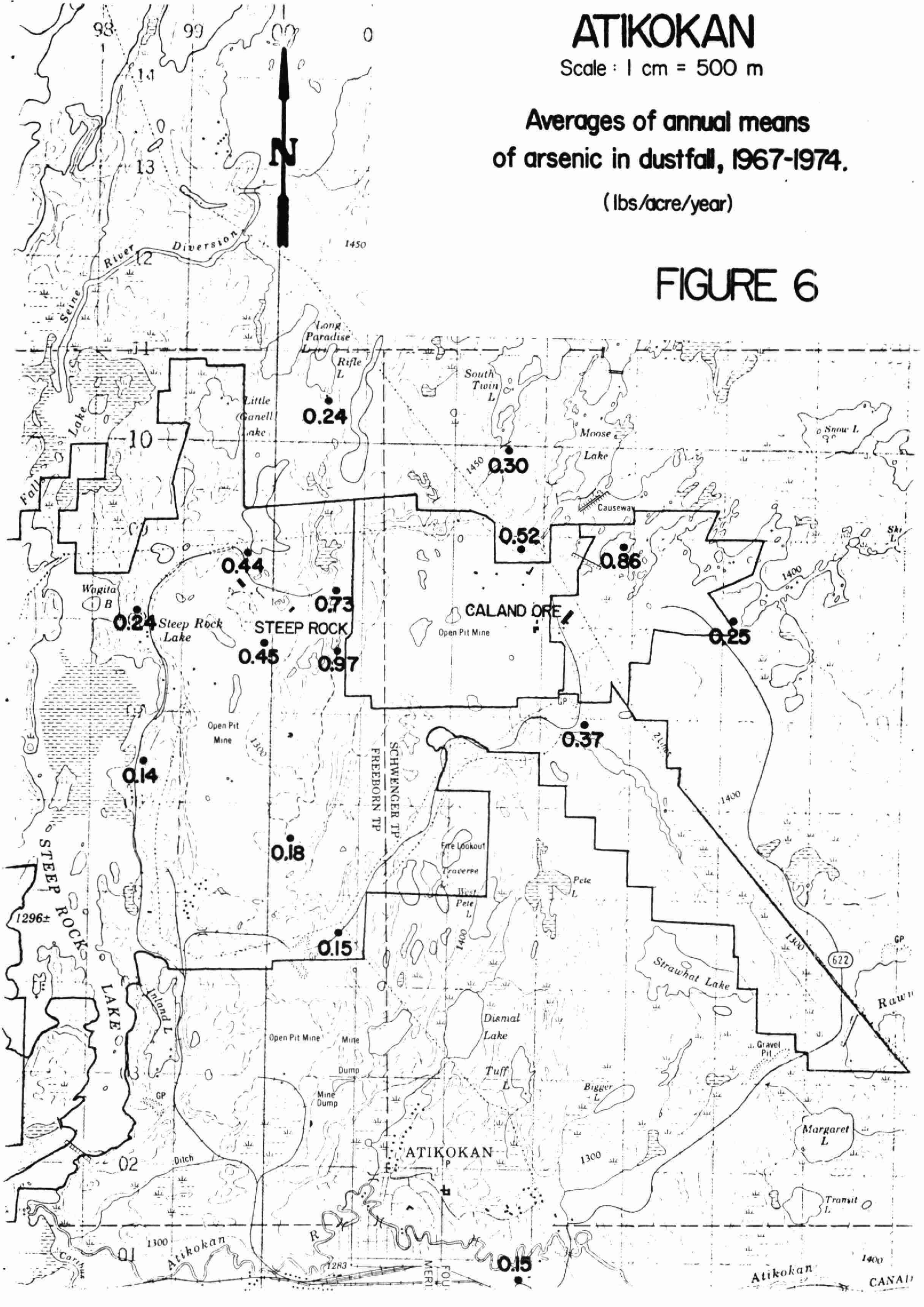
ATIKOKAN

Scale : 1 cm = 500 m

Averages of annual means of arsenic in dustfall, 1967-1974.

(lbs/acre/year)

FIGURE 6

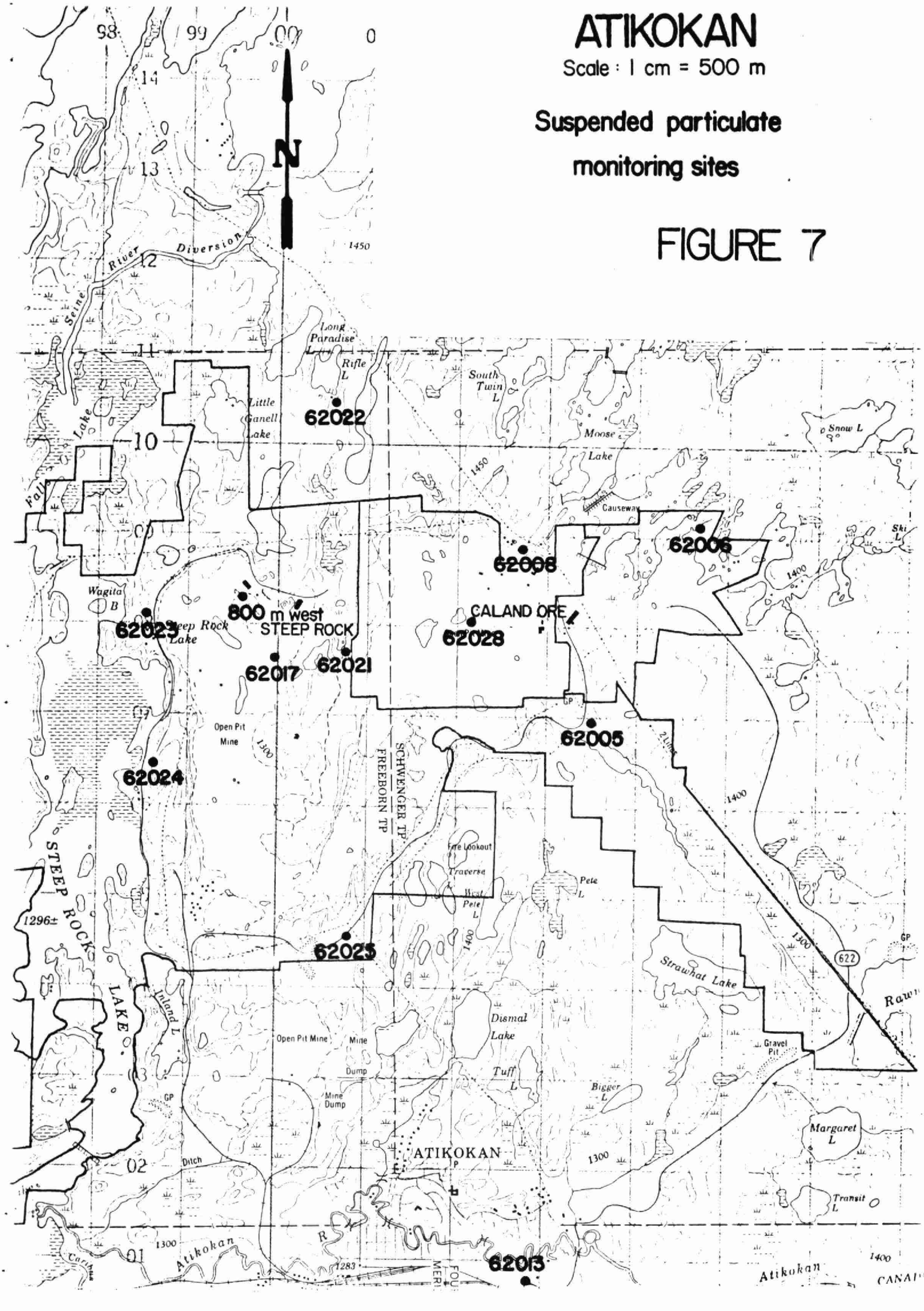


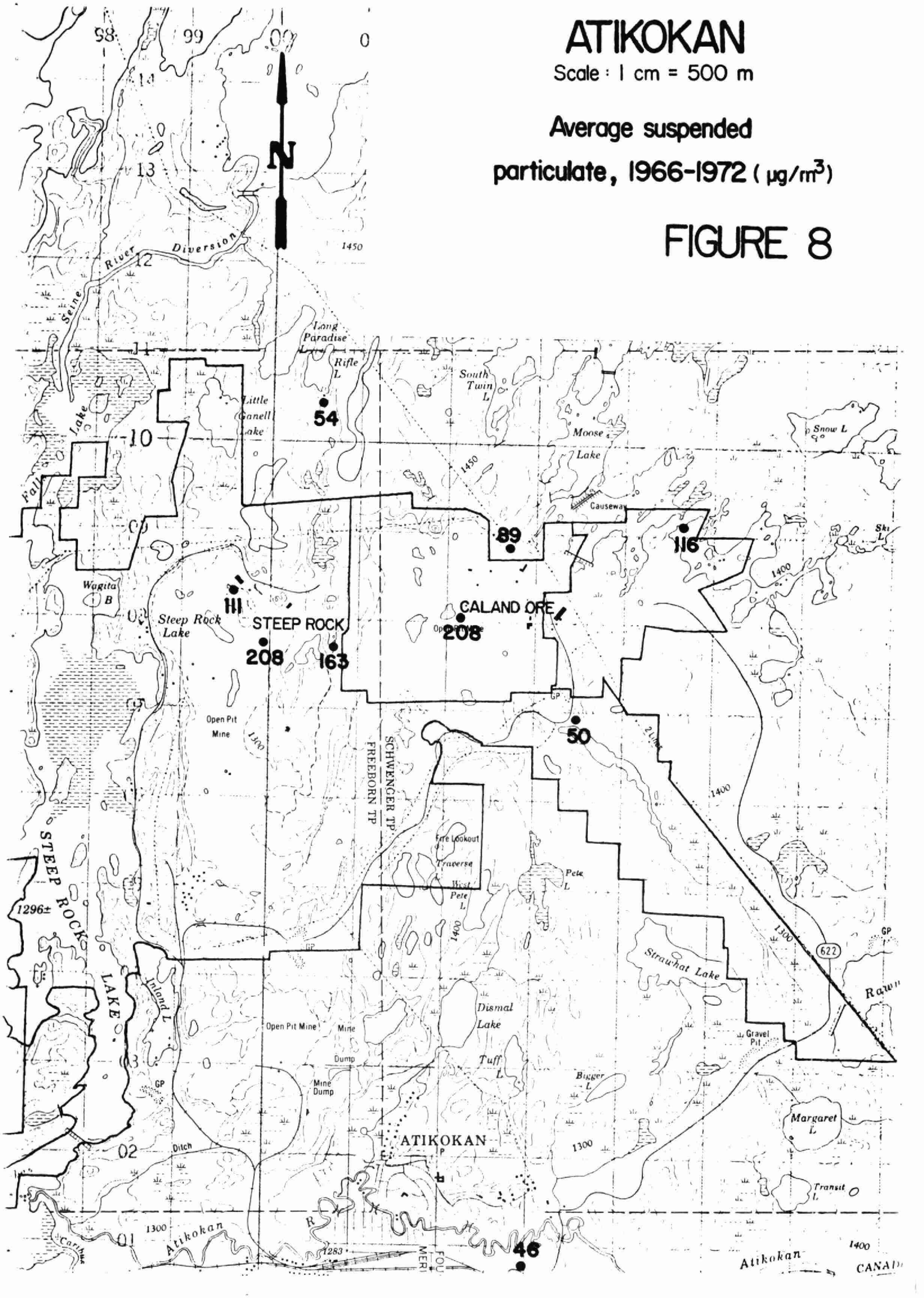
ATIKOKAN

Scale : 1 cm = 500 m

Suspended particulate monitoring sites

FIGURE 7





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Scale : 1 cm = 500 m

Average suspended particulate, 1966-1972 ($\mu g/m^3$)

FIGURE 8

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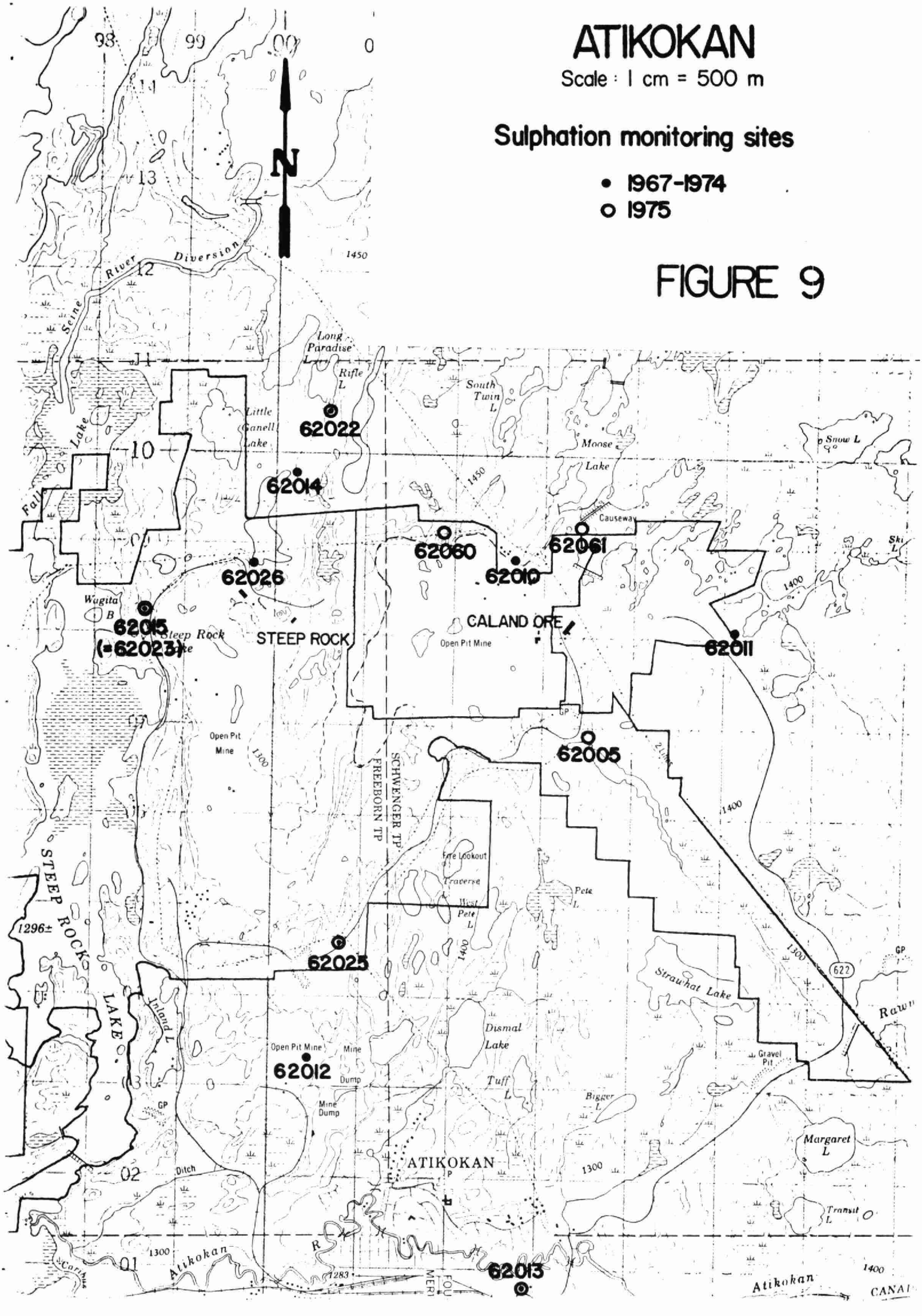
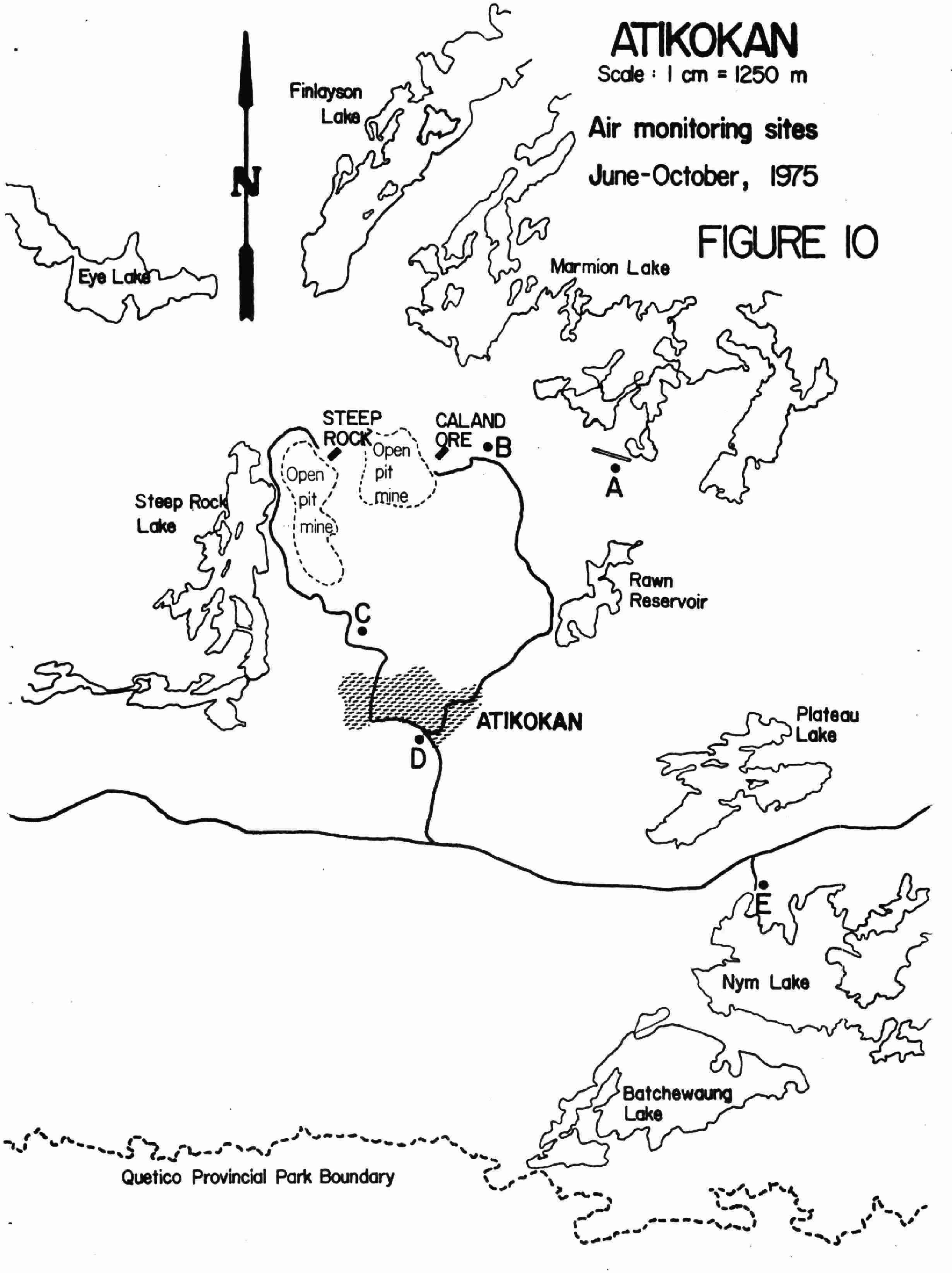
Scale : 1 cm = 500 m

Sulphation monitoring sites

- ● 1967-1974
- o 1975

FIGURE 9





ATIKOKAN
Scale : 1 cm = 1250 m
Air monitoring sites
June-October, 1975
FIGURE 10
N
Finlayson Lake
Eye Lake
Marmion Lake
STEEP ROCK
CALAND ORE
B
A
Open pit mine
Open pit mine
Steep Rock Lake
Rawn Reservoir
C
ATIKOKAN
D
Plateau Lake
E
Nym Lake
Batchewaung Lake
Quetico Provincial Park Boundary